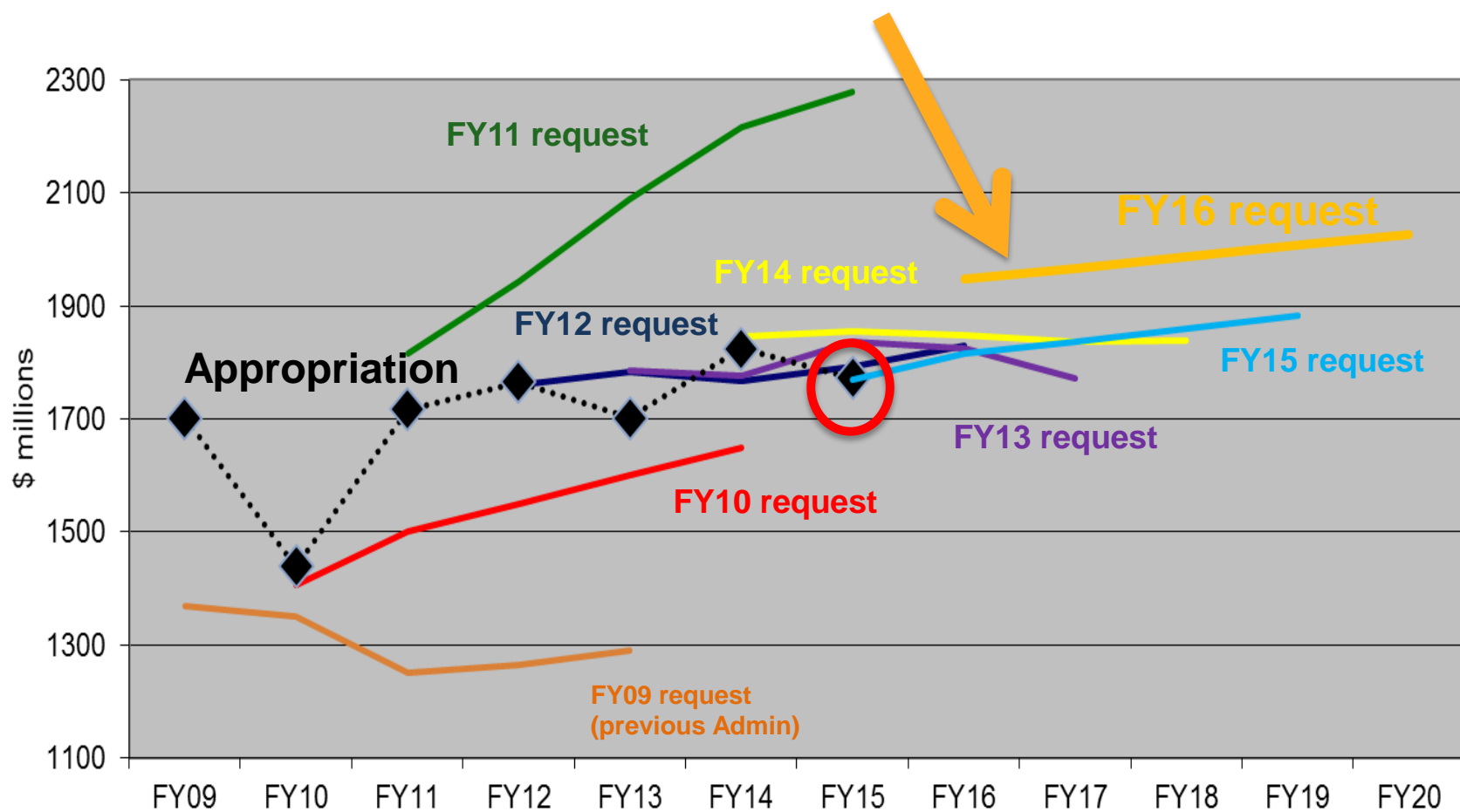National Aeronautics and Space Administration

ESD: FY16 President's Budget Request Overview and Program Status

6 April 2015

Earth Science Budget:
FY16 Request/FY15 Appropriation

- ESD budget increases significantly

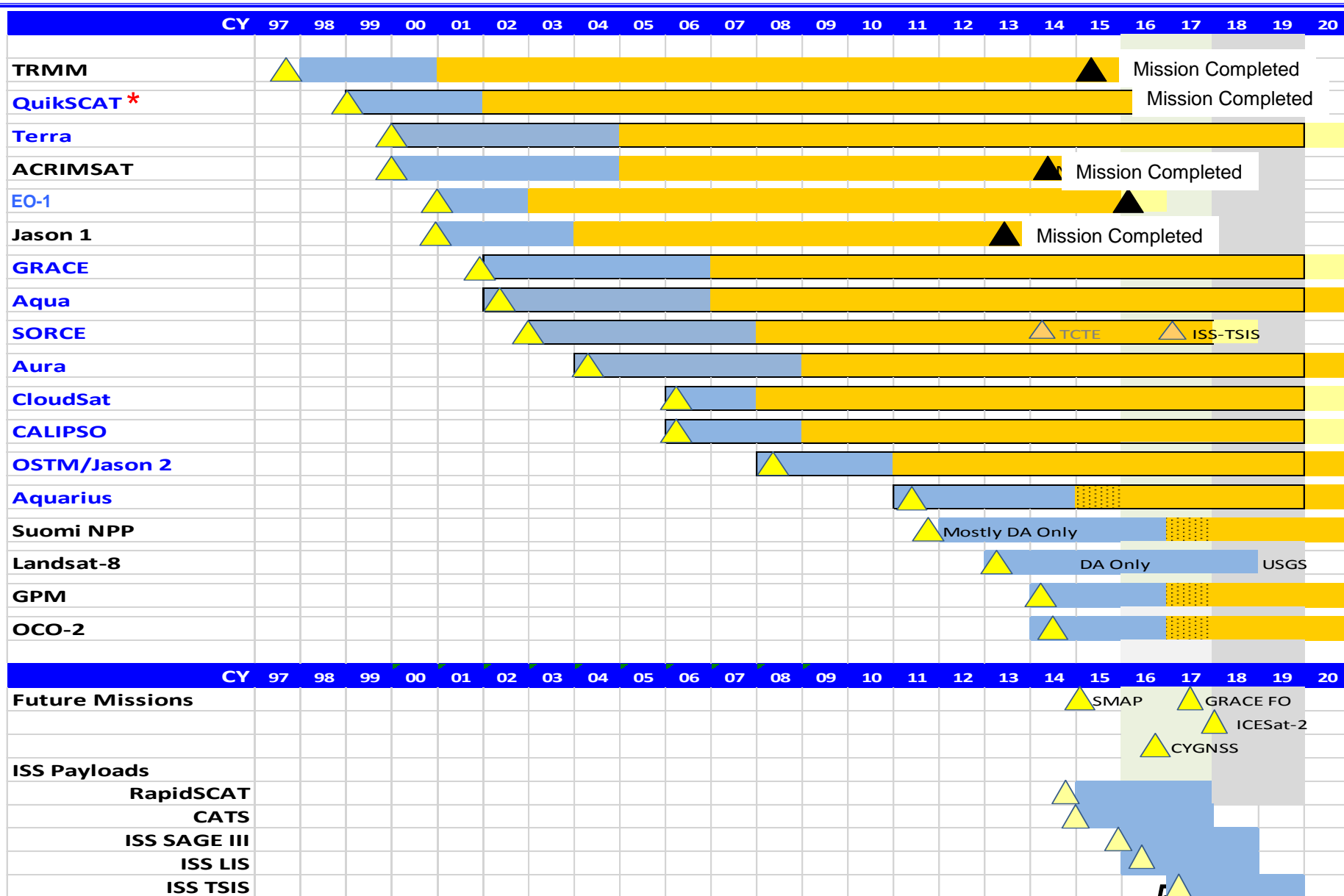|	FY15	FY16	FY17	FY18	FY19	FY20
FY16	**1.730**	**1.894**	**1.913**	**1.932**	**1.952**	**1.971**
FY15		1.762	1.784	1.805	1.829	---

- NASA now has mandate for additional long-term measurements for the nation:
  - Altimetry after Jason-3
  - Solar Irradiance, Ozone Profile, Earth Radiation Budget all starting in FY16

- Sustainable Land Imaging Program (w/USGS; NASA funds flight hardware):
  - TIR-FFD (2019)
  - Upgraded Landsat-9 (2023)
  - Focused technology development to inform designs of Landsat-10+

- Continued development and launch of: SAGE-III/ISS, ECOSTRESS/ISS, GEDI/ISS, CYGNSS, TEMPO, GRACE-FO, ICESat-2, SWOT, NISAR, PACE

- Continue Venture Class on schedule with full funding

- OCO-3 completion and flight to ISS in late 2017

- CLARREO Technology Demonstration instruments on ISS - development and flight in late 2019 (2 instruments, Reflected Solar/HySICS and IR Pathfinder)

JPSS-2 (NOAA)

SLI-TBD
Formulation in 2015

RBI
OMPS-Limb

[[TSIS-2]]

[[Future Altimetry]]

NI-SAR

PACE

SWOT

TEMPO

GRACE-FO (2)

ICESat-2

CYGNSS

RapidScat, CATS,
LIS, SAGE III (on ISS)

SMAP

SORCE   TRMM   QuikSCAT

[[TCTE]]

EO-1

Aquarius

Landsat-7
(USGS)

Suomi NPP
(NOAA)

Terra

Aqua

Landsat-8
(USGS)

CloudSat

CALIPSO

GPM

Aura

GRACE (2)

OSTM/Jason 2
(NOAA)

OCO-2

Formulation
Implementation
Primary Ops
Extended Ops

ED 2015 Senior Review Mission Set

5

3 ESD-developed EO missions launched since 2/2014
2 ISS-developed EO instruments launched (2014, 2015)
11+ more ESD EO launches before 2022

OCO-2
7/2014 ✓

SAGE-III
(on ISS)
mid-CY2016

JPSS-2 (NOAA)

RBI
OMPS-Limb

TSIS-1

[[TSIS-2]]

[[Future Altimetry]]

Grace-FO
Aug 2017 ✓

RapidSCAT, CATS ✓
(on ISS) CY2014/15

LIS
(on ISS) 2016

SLI-TIR-FFD, L9
Formulation in 2015

CLARREO*
2019 for
Pathfinders/ISS

NI-SAR
2021

EVI-3
2022

GEDI/ISS
ECOSTRESS/
ISS

✓

PACE
CY2022

EVM-2
2021

EVI-2
2020

GPM
2/2014

SWOT
CY2020

TEMPO
EVI-1,
CY2018 LRD

CYGNSS
EVM-1,
Oct 2016 LRD

ICESat-2
June 2018

SMAP
Jan 2015 ✓

SMAP First Light Image

SMAP First Light - Radar and Radiometer Data
Feb 27-28, 2015

HH Normalized Radar Cross-Section

H-Polarized Brightness Temperature
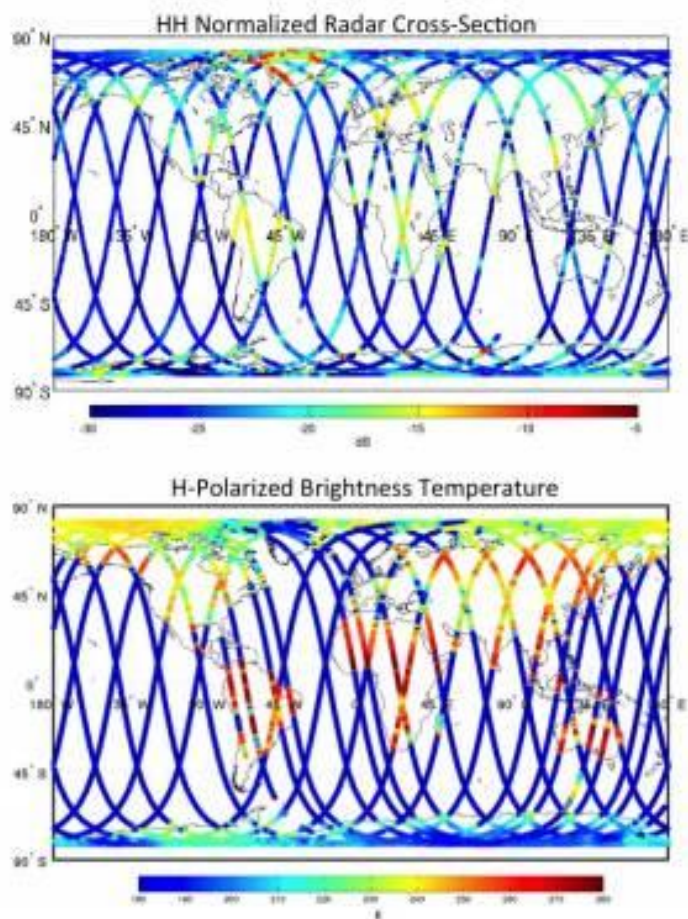
First image from a test of the radar instrument on NASA's Soil Moisture Active Passive (SMAP) satellite Feb. 27-28. The test was performed with SMAP's antenna in a non-spinning mode, which limits measurement swath widths to 40 kilometers (25 miles).

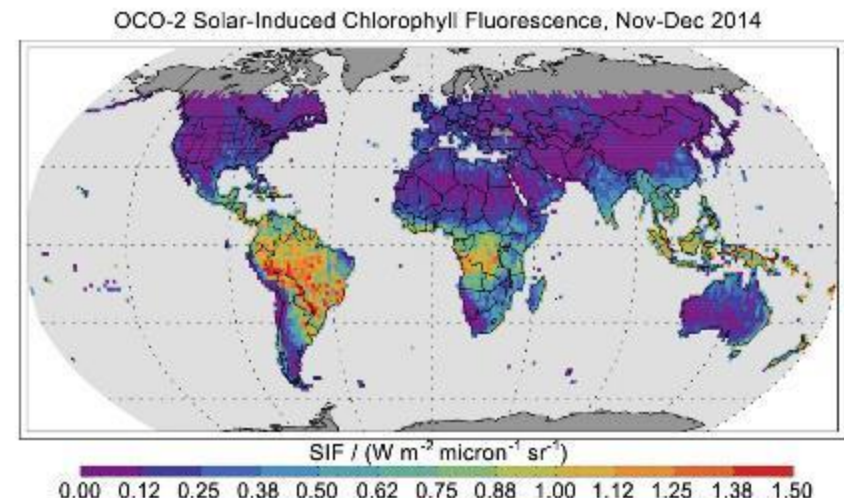*Image: NASA/JPL-Caltech/Goddard Space Flight Center*

UPDATE: **SMAP Antenna now spinning in science mode**

http://newsoffice.mit.edu/2015/first-light-images-nasa-smap-revealed-0310

OCO-2 Level 2 Product Status

- OCO-2 Level 2 products (global column CO_2 (XCO2)) are on track for release through GSFC DAAC by the end of March.
- The March 30th release will also include solar-induced fluorescence (SIF) and updated L1b files. The L1b updates correcting known deficiencies including instrument artifacts (e.g. solar cosmic rays and a minor "clocking" of slit to FPA).
- A forward data stream will arrive at the DAAC on March 30th, and backward processing at ~3x will begin shortly after. Forward data begins with March 19th. Backwards processing will extend to 9/6/14.
- The OCO-2 Science Team meeting was held Feb. 24 – 26th, 2015 in Pasadena. A broad cross section of the science team participated (118 in person, another 10 or so via webex).

- The image to the right shows a sample of the OCO-2 solar-induced fluorescence retrievals using both nadir and glint observations from 21 Nov to 29 Dec.
- The Northern Hemisphere fall Is evident in the lack of plant activity and therefore solar-induced fluorescence.
- Spring plant activity is evident in the high solar induced fluorescence values over South America, sub-Saharan Africa, and Indonesia.
- Month by month time series are consistent with the changing seasons.

OCO-2 Solar-Induced Chlorophyll Fluorescence, Nov-Dec 2014

SIF / (W m^{-2} micron^{-1} sr^{-1})

0.00 0.12 0.25 0.38 0.50 0.62 0.75 0.88 1.00 1.12 1.25 1.38 1.50

8

December 4th, 5th:

Super Typhoon Hagupit threatens the Philippines a year after deadly Super Typhoon Haiyan devastated the island nation. GPM's Microwave Imager (GMI) observed extreme rates of almost 100.9 mm (almost 4 inches) per hour on the southern side of Hagupit's eye.
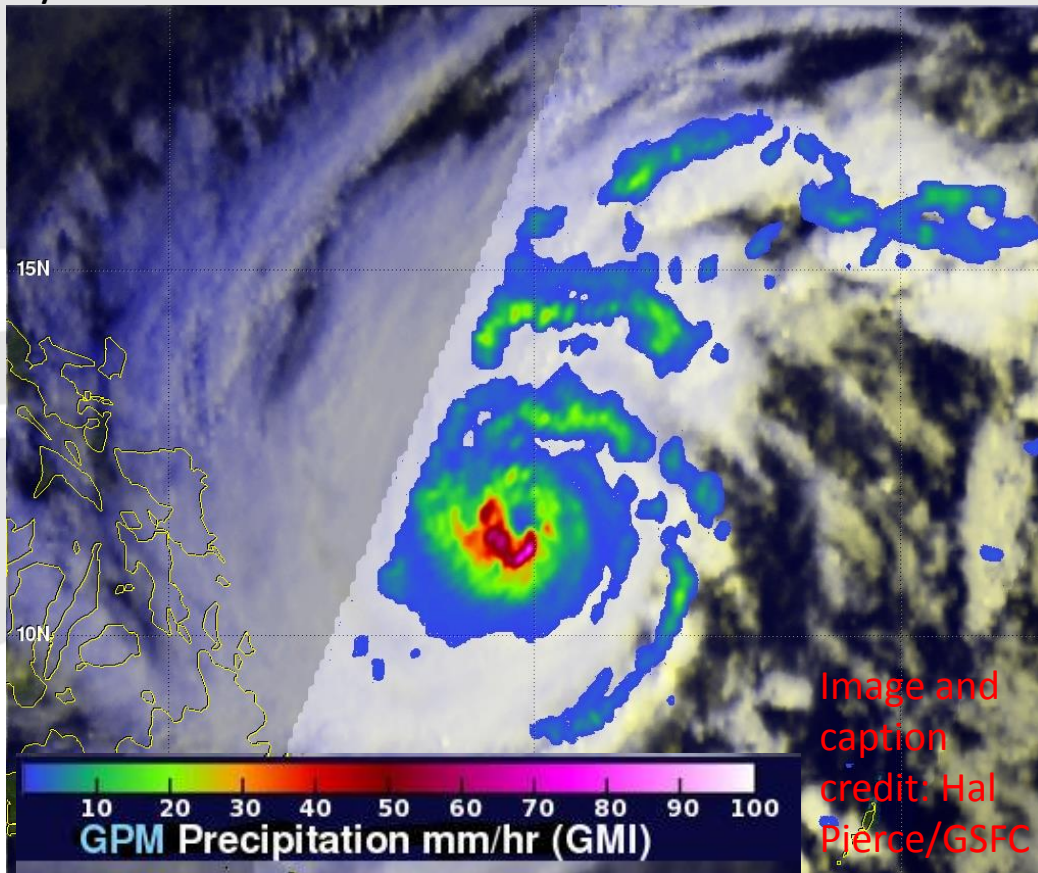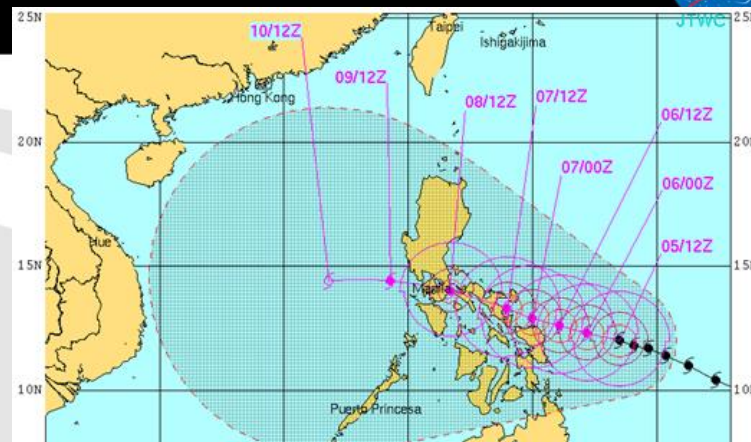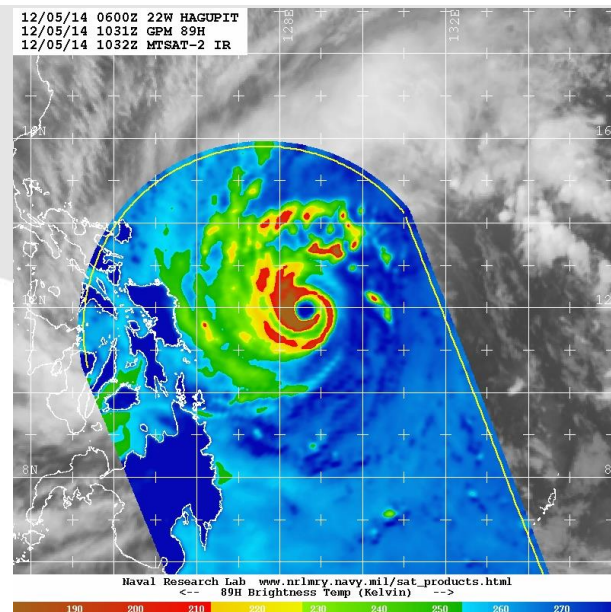
The Naval Research Lab (NRL) is using GMI and other sensors in their Automated Tropical Cyclone Forecasting System (ATCF) for improved track prediction.
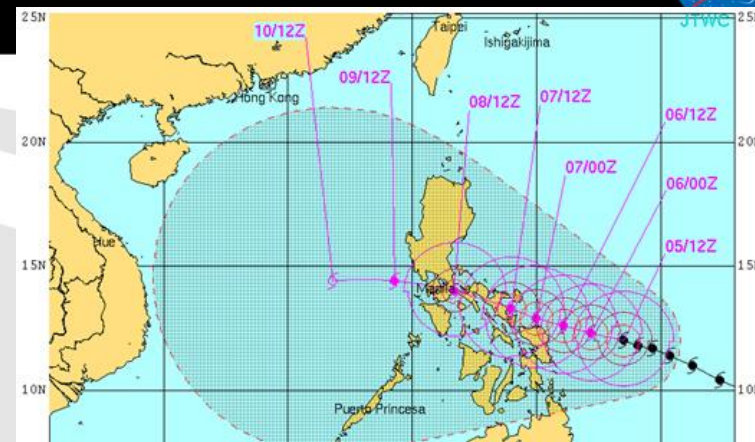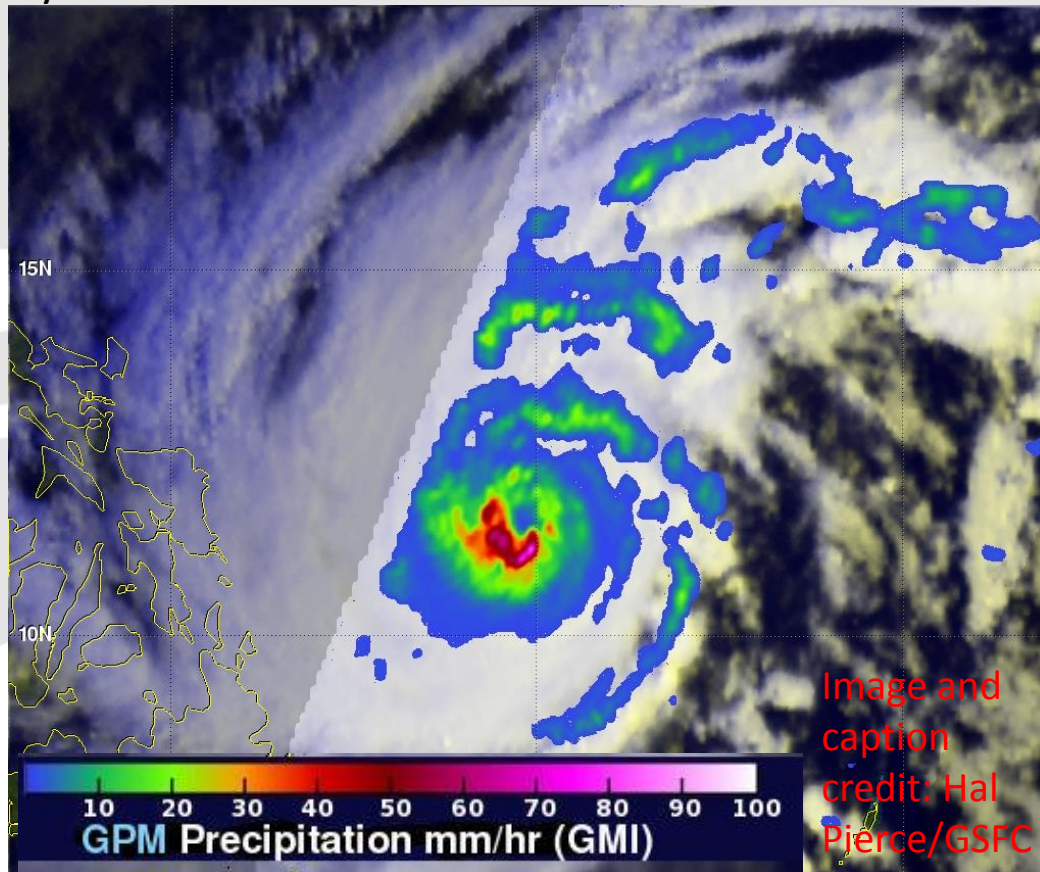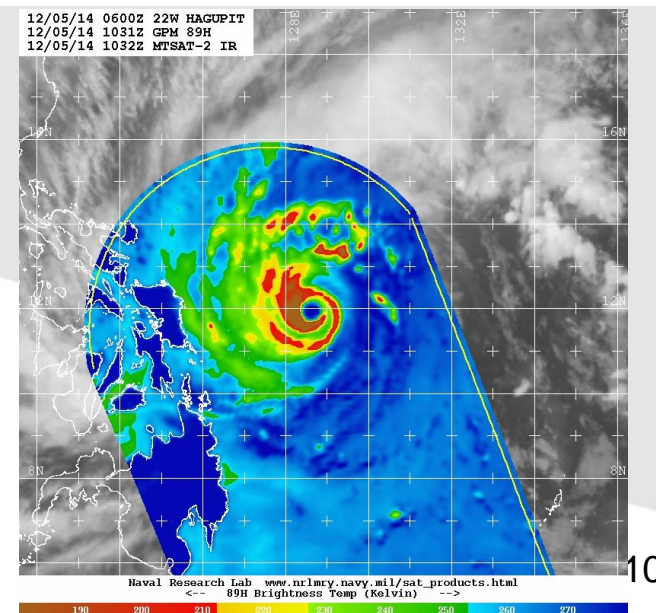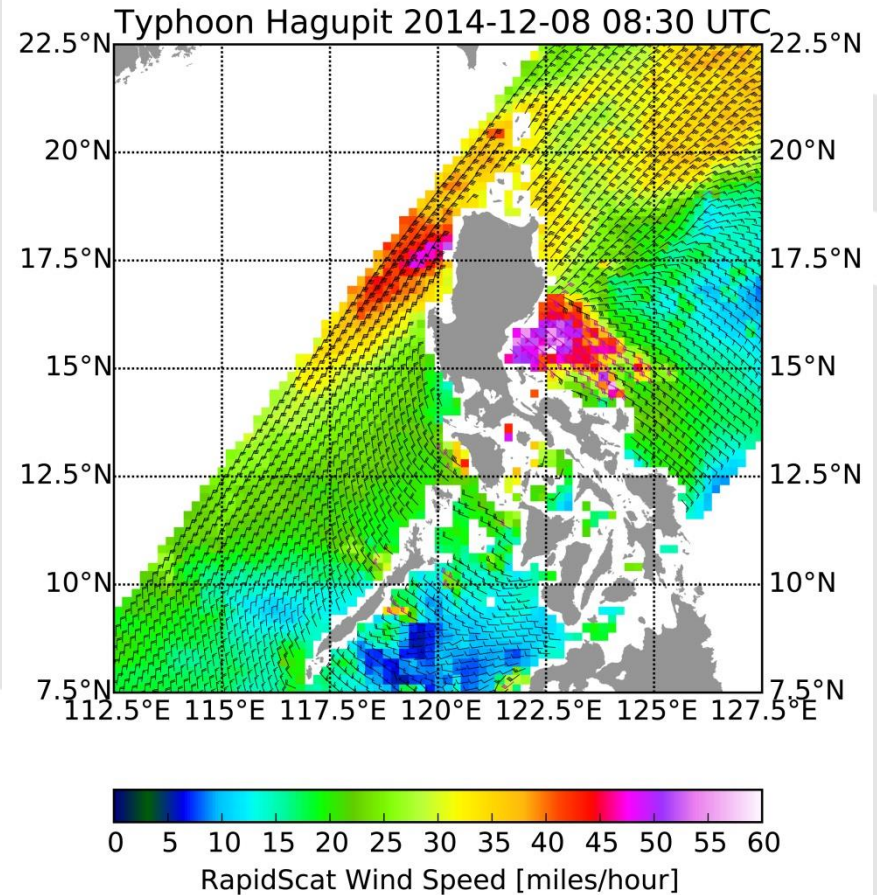
Image and caption credit: Hal Pierce/GSFC

9

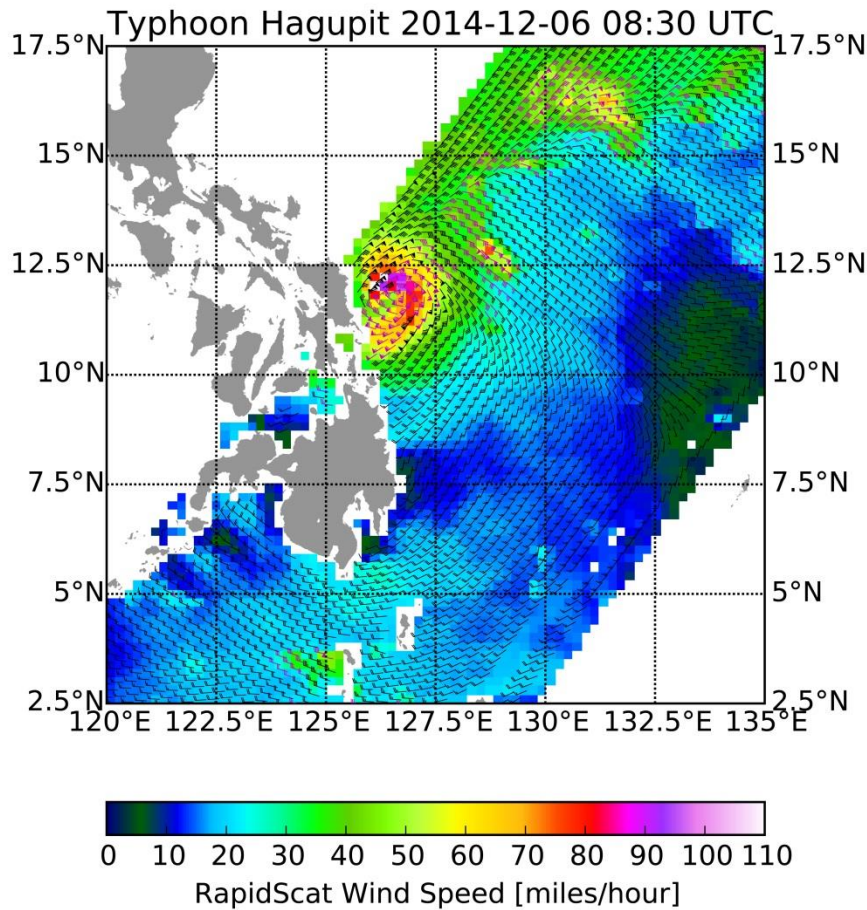http://www.nrlmry.navy.mil/tc_pages/tc_home.html

December 4th, 5th:

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Image and caption credit: Hal Pierce/GSFC

GPM Precipitation mm/hr (GMI)
10 20 30 40 50 60 70 80 90 100

12/05/14 0600Z 22W HAGUPIT
12/05/14 1031Z GPM 89H
12/05/14 1032Z MTSAT-2 IR

Naval Research Lab   www.nrlmry.navy.mil/sat_products.html
89H Brightness Temp (Kelvin)
190 200 210 220 230 240 250 260 270

http://www.nrlmry.navy.mil/tc_pages/tc_home.html

RapidScat Measurements of Hagupit

Note speed scale difference

Image Credit: NASA/JPL-Caltech/NOAA

- **February 27, 2014 13:37 EST**: Launch
- **May 29, 2014:** Commissioning ends, prime mission operations begins
- **May & Dec 2014**: Deep Space Calibrations for GMI
- **March-August 2014**: Calibration checks and updates for DPR
- **June 2014 (early public release)**: GMI brightness temperature data (used by operational users for the summer hurricane and cyclone season)
- **July 2014 (early public release)**: GMI data with precipitation rates
- **September 2014 (Core Observatory Products)**: DPR & Combined DPR+GMI precipitation rate data released to the public
  - High quality research products
  - Near real time application/operations products (data within 1-4 hrs)
- **January 2015 (Merged Constellation Products)**: NASA's Integrated Multi-Satellite Retrievals for GPM (IMERG) released
- **Feb 27, 2015 (1yr)**: GPM Core Observatory completes ~5700 orbits
- **May 2017**: End of Prime Mission
- **2019-2029**: Potential lifetime of onboard fuel (with reserves for reentry)
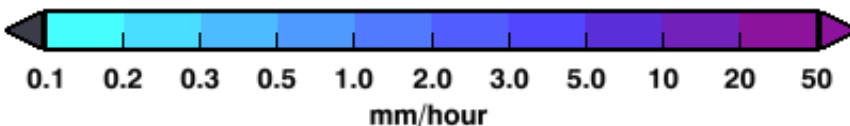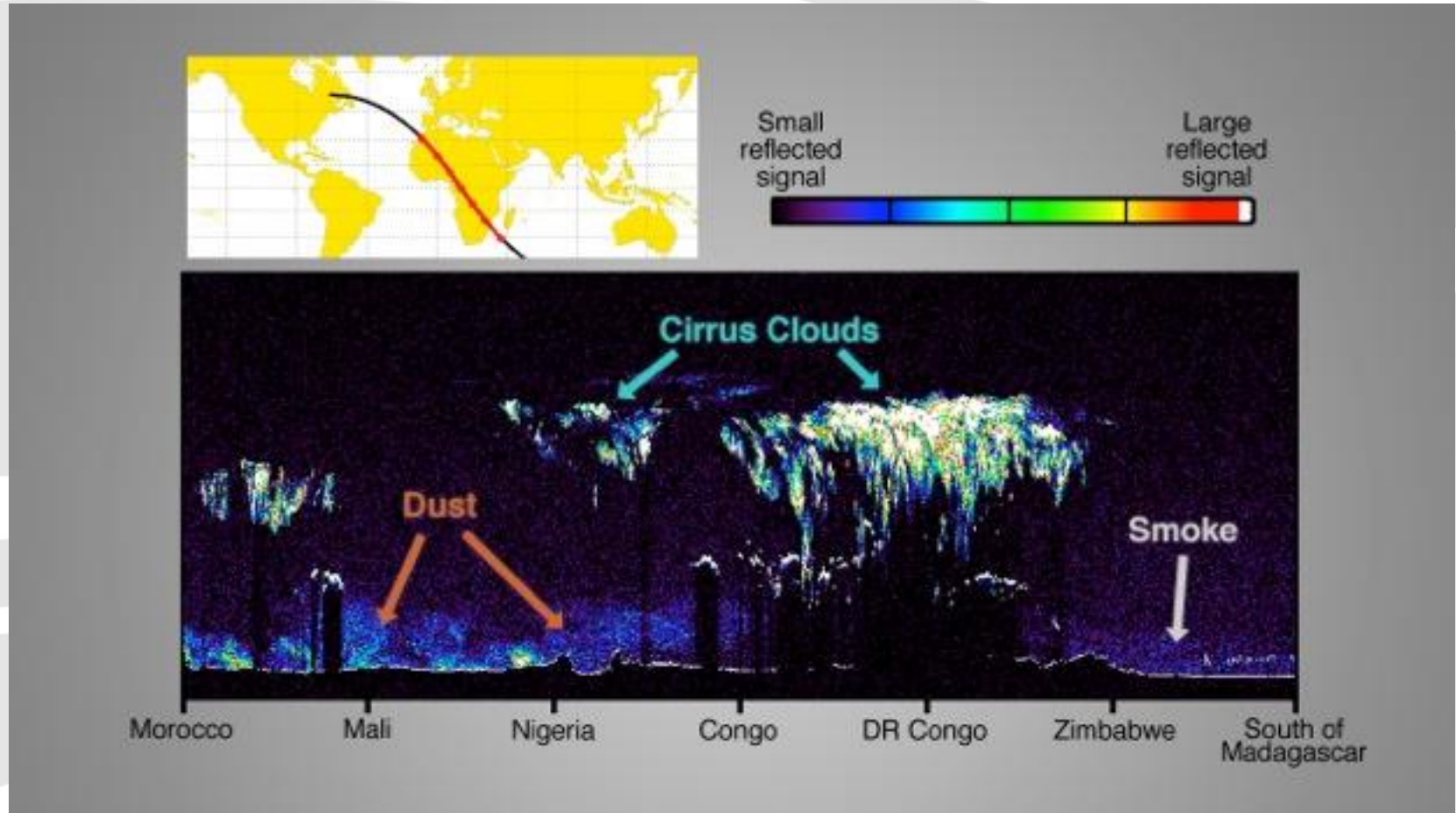
IMERG: Integrated Multi-satellitE Retrievals for GPM
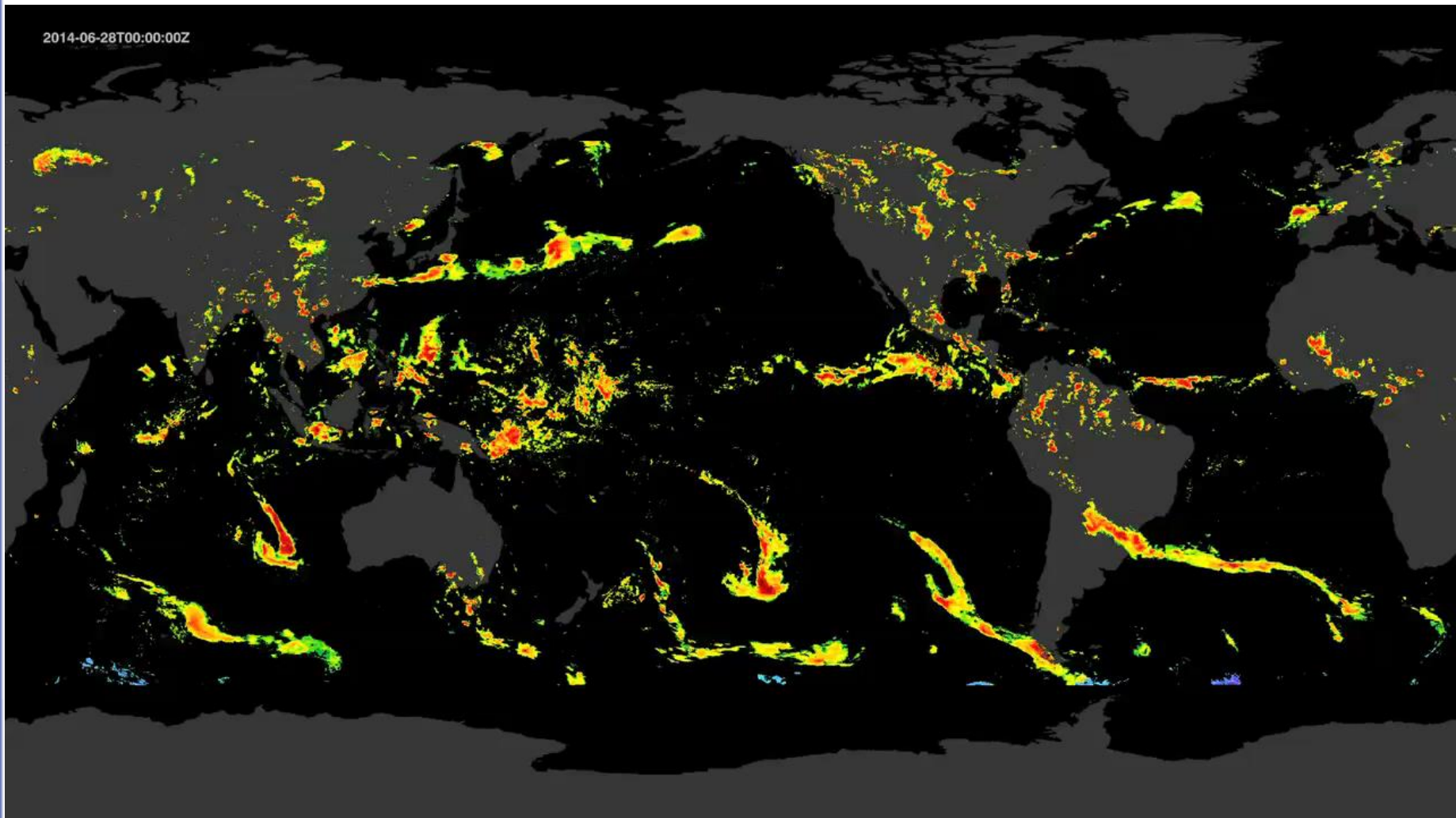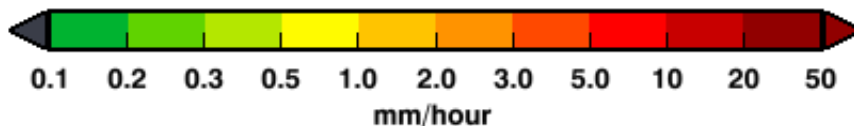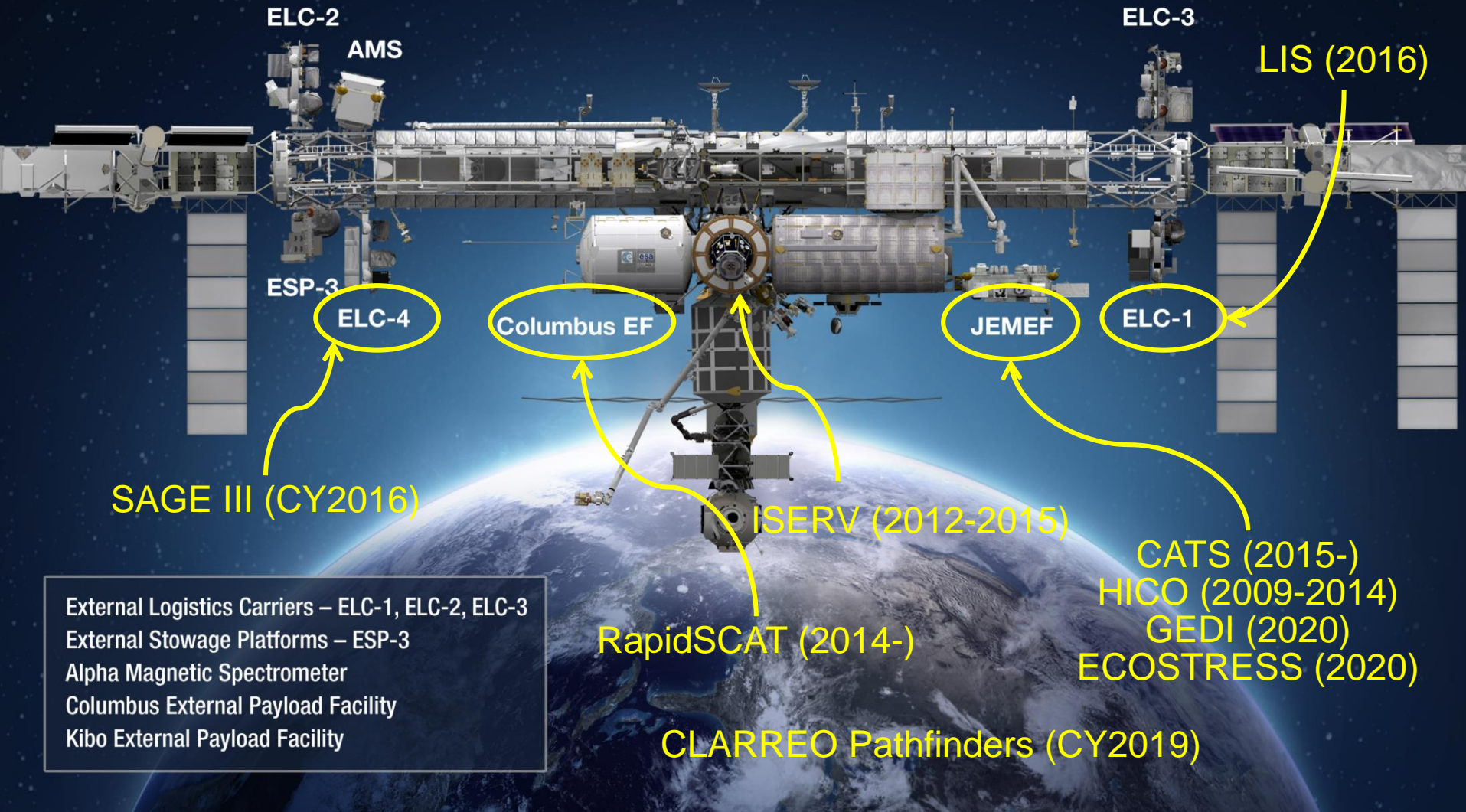
The CATS image shows a profile of particles in the atmosphere over a swath of Africa, from 30 degrees North to 30 degrees South, as the space station flew over it in the early morning of Feb. 11.

International Space Station
Earth Science Instruments

ELC-2
AMS
ELC-3
LIS (2016)

ESP-3
ELC-4
Columbus EF
JEMEF
ELC-1

SAGE III (CY2016)

ISERV (2012-2015)

CATS (2015-)
HICO (2009-2014)
GEDI (2020)
ECOSTRESS (2020)

RapidSCAT (2014-)

External Logistics Carriers – ELC-1, ELC-2, ELC-3
External Stowage Platforms – ESP-3
Alpha Magnetic Spectrometer
Columbus External Payload Facility
Kibo External Payload Facility

CLARREO Pathfinders (CY2019)

Venture Class Selections/Solicitations

Mission	Mission Type	Solicitation Release	Proposal Selection	Major Milestone	Total Funding*
EVI-3	Instrument Only	Q2 FY2015	Q2 FY2016	Delivery NLT 2020	$130M
EVI-4	Instrument Only	Q4 FY2016	Q4 FY2017	Delivery NLT 2021	$150M
EVI-5	Instrument Only	Q2 FY2018	Q2 FY2019	Delivery NLT 2023	$182M
EVI-6	Instrument Only	Q4 FY2019	Q4 FY2020	Delivery NLT 2024	$155M
EVI-7	Instrument Only	Q2 FY2021	Q2 FY2022	Delivery NLT 2025	$185M
EVM-2	Full Orbital	Q3 FY2015	Q3 FY2016	Launch ~2021	$165M
EVM-3	Full Orbital	Q3 FY2019	Q3 FY2020	Launch ~2025	$179M
EVS-2	**Suborbital**	**Q4 FY2013**	**Q1 FY2015**	**2016-2020**	**$162M**
EVS-3	Suborbital	Q4 FY2017	Q4 FY2018	2019-2023	$176M

Most recent Selection   * Funding for future EVs is approximate and will be adapted depending on previous selections.

EVS-1: CARVE, ATTREX, DISCOVER-AQ, AirMOSS, HS-3
EVM-1: CYGNSS (2016 LRD)
EVI-1: TEMPO (2017 Instrument Delivery)
EVI-2: GEDI, ECOSTRESS (2019 Inst. Del.)
EVS-2: AtoM, NAAMS, OMG, ORACLES, ACT-America

Atmospheric Tomography Experiment (ATom) – Harvard University (Steve Wofsy)

This investigation will study the impact of human-produced air pollution on certain greenhouse gases. Airborne instruments will look at how atmospheric chemistry is transformed by various air pollutants and at the impact on methane and ozone which affect climate. Flights aboard NASA's DC-8 will originate from the Armstrong Flight Research Center in Palmdale, California, fly north to the western Arctic, south to the South Pacific, east to the Atlantic, north to Greenland, and return to California across central North America.

North Atlantic Aerosols and Marine Ecosystems Study (NAAMES) – Oregon State U. (Mike Behrenfeld)

This investigation will improve predictions of how ocean ecosystems would change with ocean warming. The mission will study the annual life cycle of phytoplankton and the impact small airborne particles derived from marine organisms have on climate in the North Atlantic. The large annual phytoplankton bloom in this region may influence the Earth's energy budget. Research flights by NASA's C-130 aircraft from Wallops Flight Facility, Virginia, will be coordinated with a University-National Oceanographic Laboratory System (UNOLS) research vessel.

**Atmospheric Carbon and Transport – America – Penn State University (Kenneth Davis)**

This investigation will quantify the sources of regional carbon dioxide, methane and other gases, and document how weather systems transport these gases in the atmosphere. The research goal is to improve identification and predictions of carbon dioxide and methane sources and sinks using spaceborne, airborne and ground-based data over the eastern United States. Research flights will use NASA's C-130 from Wallops and the UC-12 from Langley Research Center in Hampton, Virginia.

ObseRvations of Aerosols Above Clouds and Their IntEractionS (ORACLES) – ARC (Jens Redemann)

ORACLES will probe how smoke particles from massive biomass burning in Africa influences cloud cover over the Atlantic. Particles from this seasonal burning that are lofted into the mid-troposphere and transported westward over the southeast Atlantic interact with permanent stratocumulus "climate radiators," which are critical to the regional and global climate system. NASA aircraft, including a Wallops P-3 and an Armstrong ER-2, will be used to conduct the investigation flying out of Walvis Bay, Namibia.

Oceans Melting Greenland (OMG) – JPL (Josh Willis)

The objective of OMG is to investigate the role of warmer saltier Atlantic subsurface waters in Greenland glacier melting. The study will help pave the way for improved estimates of future sea level rise by observing changes in glacier melting where ice contacts seawater. Measurements of the ocean bottom as well as seawater properties around Greenland will be taken from ships and the air using several aircraft including a NASA S-3 from Glenn Research Center in Cleveland, Ohio, and Gulfstream III from Armstrong.
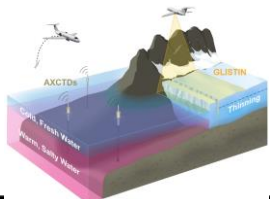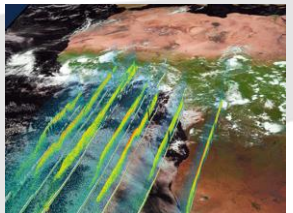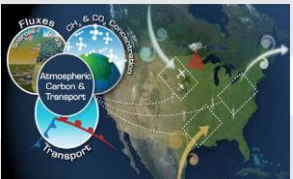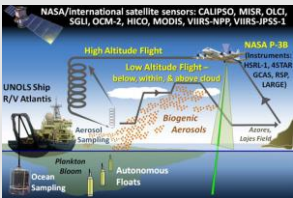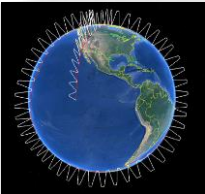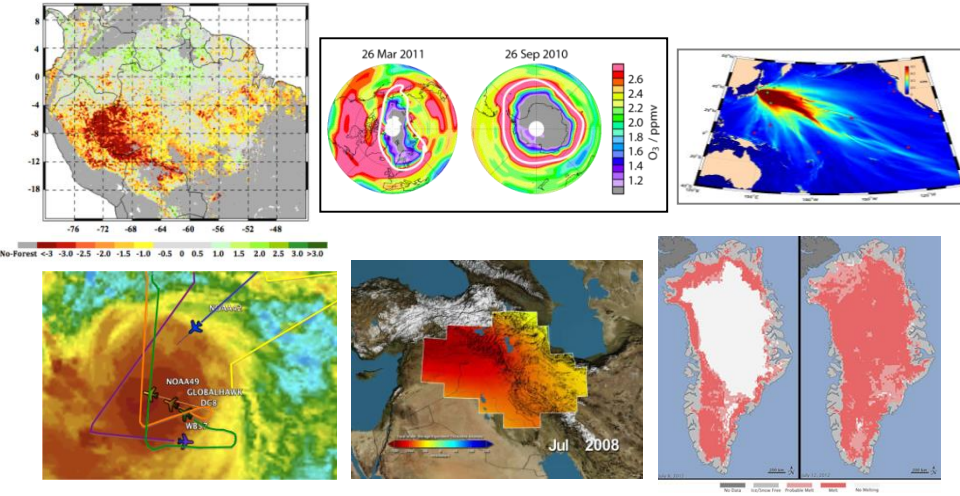
NASA's Earth Science Division
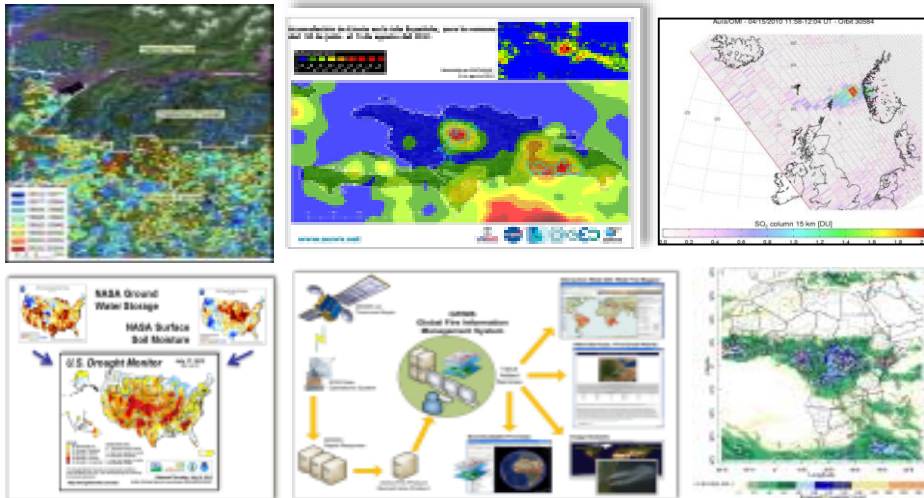
Research

Flight
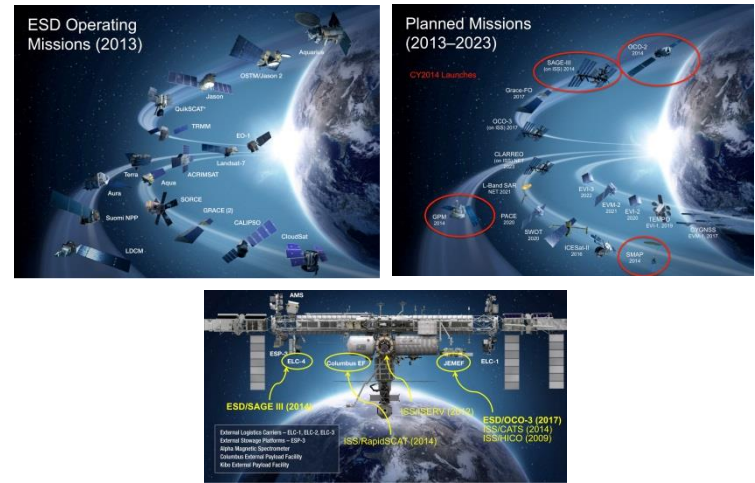

Applied Sciences

Technology

- ## Earth Science Research

	FY15	FY16	FY17	FY18	FY19	FY20
FY16	**399**	**432**	**417**	**425**	**418**	**414**
FY15		424	400	390	392	---

  ✧ Includes funding to improve understanding of coupled North Atlantic-Arctic system

  ✧ Includes additional funding for research to understand linkages between oceans and climate

  ✧ Funds CDI, BEDI/GCIS, CRT/Citizen Science

- ## Applied Sciences

	FY15	FY16	FY17	FY18	FY19	FY20
FY16	**40.4**	**47.6**	**48.7**	**48.4**	**47.6**	**48.8**
FY15		38.0	38.7	39.8	39.8	---

  ✧ Will be used to accelerate ramp-up of Water and Food Security initiatives

- Earth Science Technology Office

	FY15	FY16	FY17	FY18	FY19	FY20
FY16	**59.7**	**60.7**	**62.1**	**61.5**	**61.2**	**62.7**
FY15		54.5	55.6	55.5	55.6	---

✧Increase for the InVEST program (~ $5M/year additional)

The need to space-validate new technologies is critical to reduce risk for future Earth science measurements. The In-Space Validation of Earth Science Technologies (InVEST) program is intended to fill the gap. The first InVEST solicitation in 2012 sought small instruments and subsystems that advance technology to enable relevant measurements and targeted the CubeSat platform.

The *Microwave Radiometer Technology Acceleration (MiRaTA) CubeSat* will validate multiple subsystem technologies and demonstrate new miniature microwave radiometers operating near 52-58, 175-191, and 206-208 GHz that could dramatically enhance the capabilities of future temperature and humidity measurements.   - K. Cahoy, MIT; **Launch NET 2016**
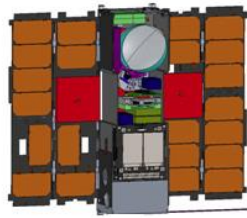
The *Radiometer Assessment Using Vertically Aligned Nanotubes (RAVAN)* project will demonstrate a bolometer radiometer that is compact, low cost, and absolutely accurate to NIST traceable standards. RAVAN could lead to affordable CubeSat constellations that, in sufficient numbers, might measure Earth's radiative diurnal cycle and absolute energy imbalance to climate accuracies (globally at 0.3 W/m2) for the first time.   - W. Swartz, JHU/APL; **Launch NET 2016**

The objective of the *CubeSat Flight Demonstration of a Photon Counting Infrared Detector (LMPC CubeSat)* is to demonstrate in space, a new detector with high quantum efficiency and single photon level response at several important remote sensing wavelength detection bands from 1 to 2 microns.   - R. Fields, Aerospace Corporation; **Launch NET 2016**
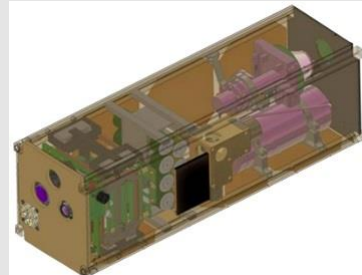
The *HyperAngular Rainbow Polarimeter HARP-CubeSat* will validate a technology required by the Aerosol-Cloud-Ecosystem (ACE) mission concept and prove the capabilities of a highly-accurate, wide-FOV, hyperangle, imaging polarimeter for characterizing aerosol and cloud properties.
- J. V. Martins, UMBC; **Launch NET 2016**

IceCube is a three unit (3U) CubeSat under development to validate a 874-GHz radiometer receiver for future use in ice cloud measurement missions. This submillimeter wave radiometer technology could directly benefit an ice cloud imaging radiometer such as that called for by the Aerosol-Cloud-Ecosystem (ACE) mission concept.
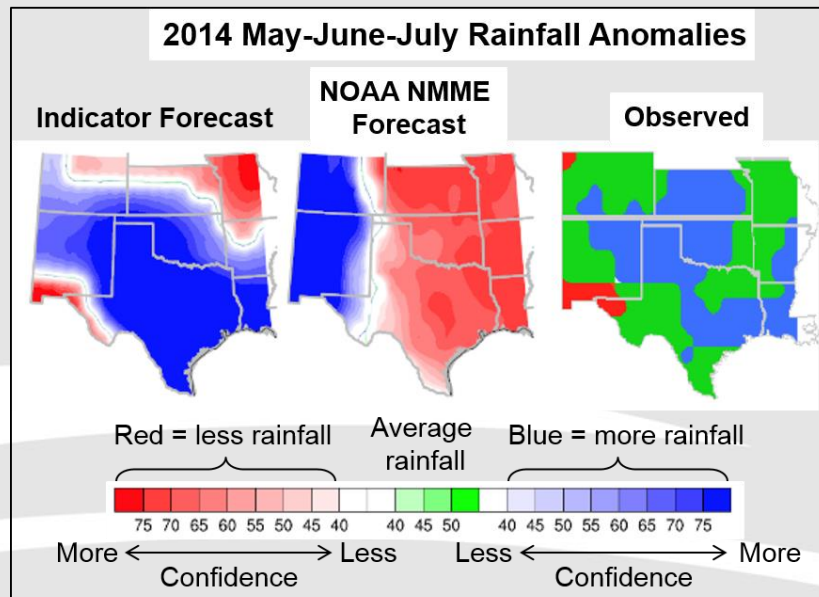- D. Wu, NASA Goddard Space Flight Center; **Launch NET 2016**
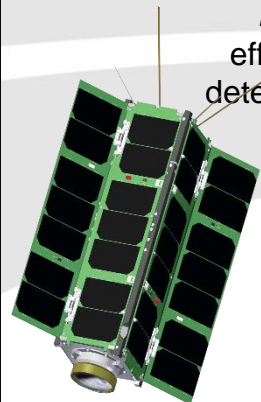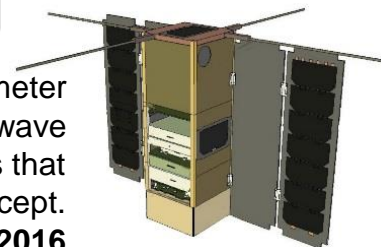
Early Warning of Summer Drought over Texas and the South Central U.S.
PI: Rong Fu, University of Texas - Austin

2014 May-June-July Rainfall Anomalies

Indicator Forecast | NOAA NMME Forecast | Observed

Red = less rainfall | Average rainfall | Blue = more rainfall

75 70 65 60 55 50 45 40 | 40 45 50 | 40 45 50 55 60 65 70 75

More ← Confidence → Less | Less ← Confidence → More

Timing of Arctic Sea Ice Advance and Retreat as an Indicator of Ice-Dependent Marine Mammal Habitat
PI: Harry Stern, University of Washington, Seattle

Dates of fall sea-ice advance

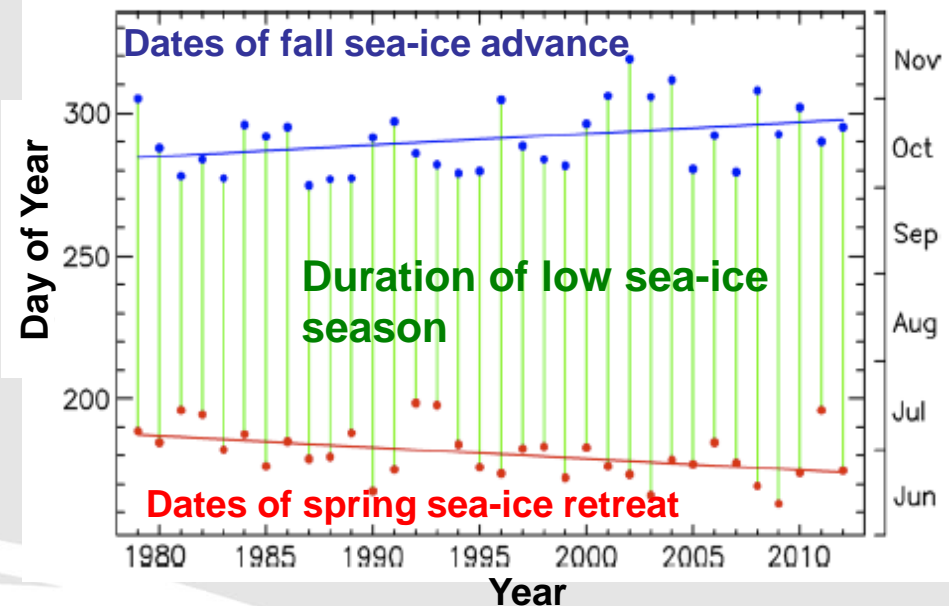Duration of low sea-ice season

Dates of spring sea-ice retreat

Statistical indicator for summer rainfall and drought prediction
- 70% effectiveness
- Outperforms existing models
- Utilizes data from MERRA
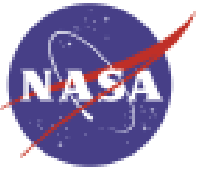- Published report with the Texas Water Development Board

Habitat change indicator for ice dependent marine mammals
- Utilizes data from NSIDC
- Polar bear results are being used by Canada, Nunavut, Greenland, and the International Union for Conservation of Nature Red List and Polar Bear Specialist Group

HECC is Used to Clear 5 Years of UAVSAR Data Processing Backlog and Reduce Latency

Impact: Enabled by NASA's Pleiades supercomputer, UAVSAR was able to clear a 5-year processing backlog to deliver surface deformation products to scientists for research.

UAVSAR Interferometric image (May 29 & August 29, 2014)

- Scientists are using repeat-pass interferometric (InSAR) data from Uninhabited Airborne Vehicle Synthetic Aperture Radar (UAVSAR) to study centimeter-scale surface deformation of earthquake faults, volcanoes, landslides, and glaciers.

- The computationally intensive InSAR processing code was ported to Pleiades Supercomputer at Ames to take advantage of the large number of processing nodes, each with more than 32 GB RAM, and ample data storage.

- With Pleiades and processor automation, HECC was able to clear a 5-year InSAR processing backlog in 6 months and reduce processing latency to 2 weeks.
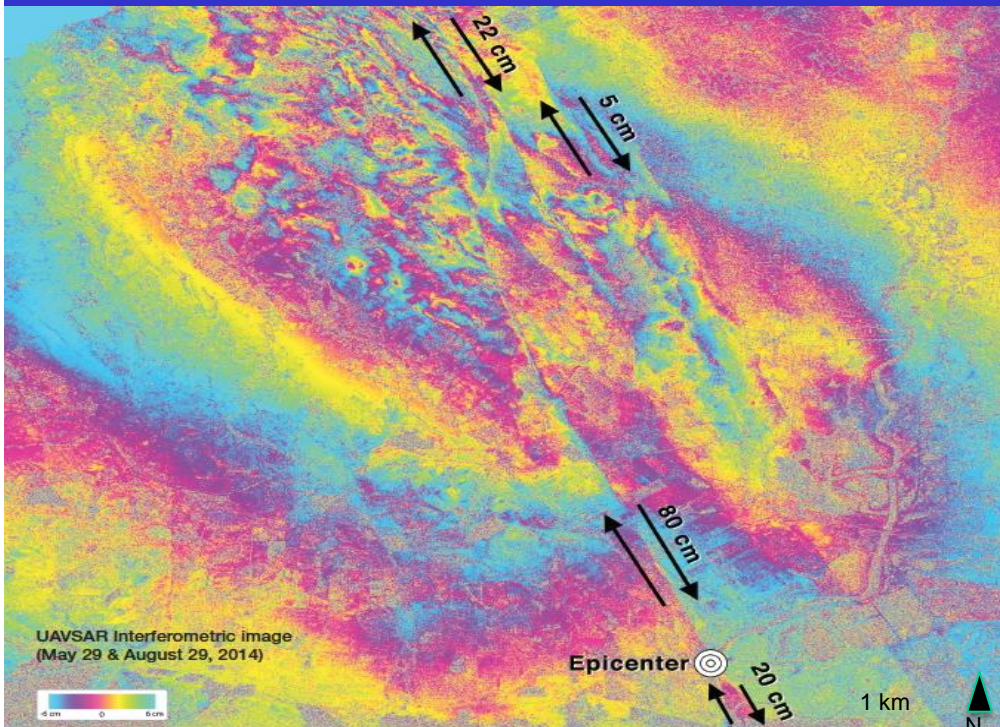
UAVSAR Interferometric image (May 29 & Aug 29, '14) of the M6.0 South Napa Earthquake, CA. Colors in the image represent the amount of ground motion between the two flights from the radar's point of view. Linear discontinuities in the colors indicate locations where a surface rupture is highly likely.
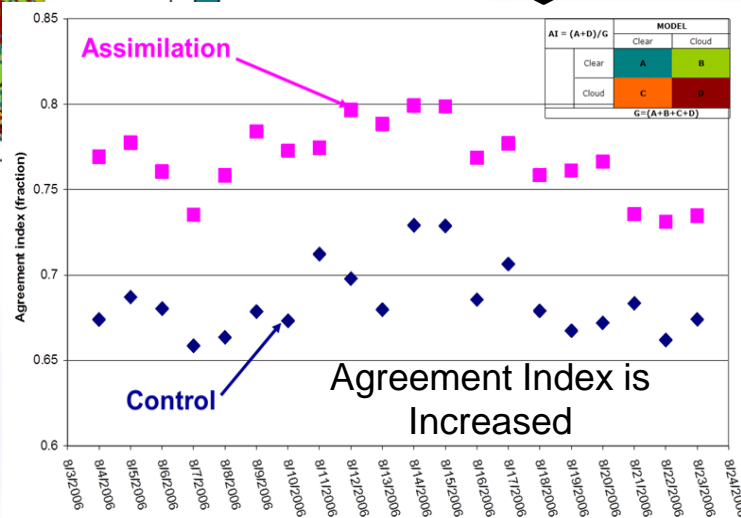
Andrea Donnellan, NASA/JPL

Incorporating Space-borne Measurements to Improve Air Quality Decision Support Systems for Texas
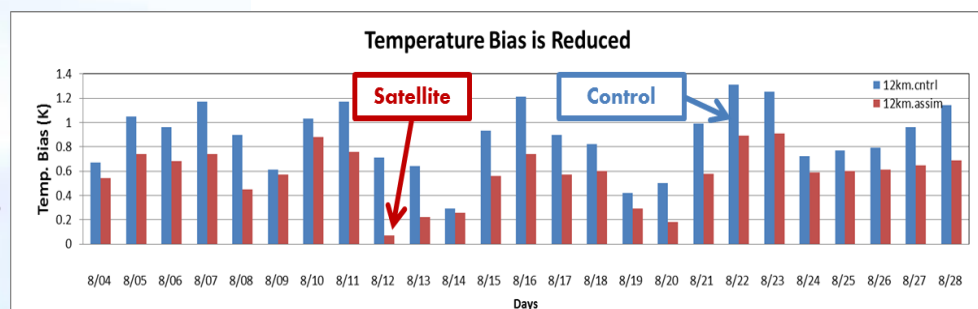

CLOUD LOCATIONS & TIMING FROM SATELLITE INGESTED INTO THE AIR QUALITY MODEL USED TO PLAN ACCEPTABLE EMISSIONS
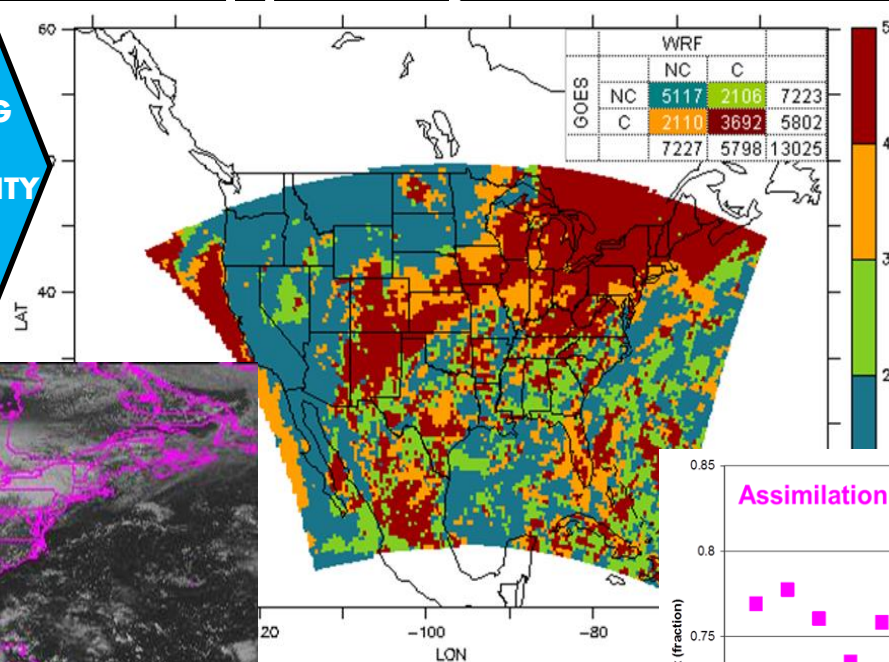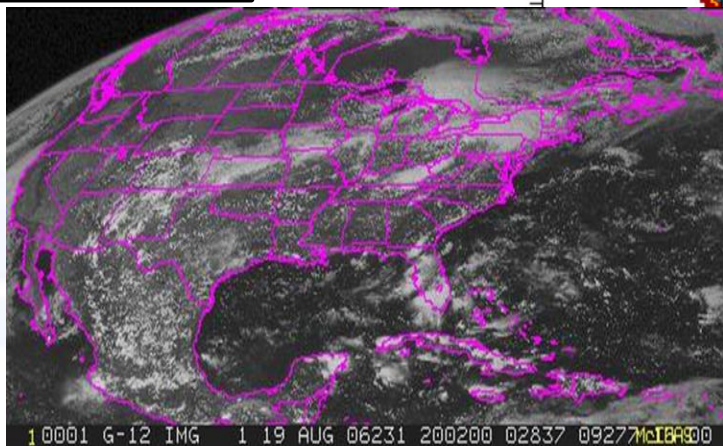
IMPROVED AIR QUALITY PLANNING AND REGULATORY DECISIONS

Agreement Index is Increased

Temperature Bias is Reduced
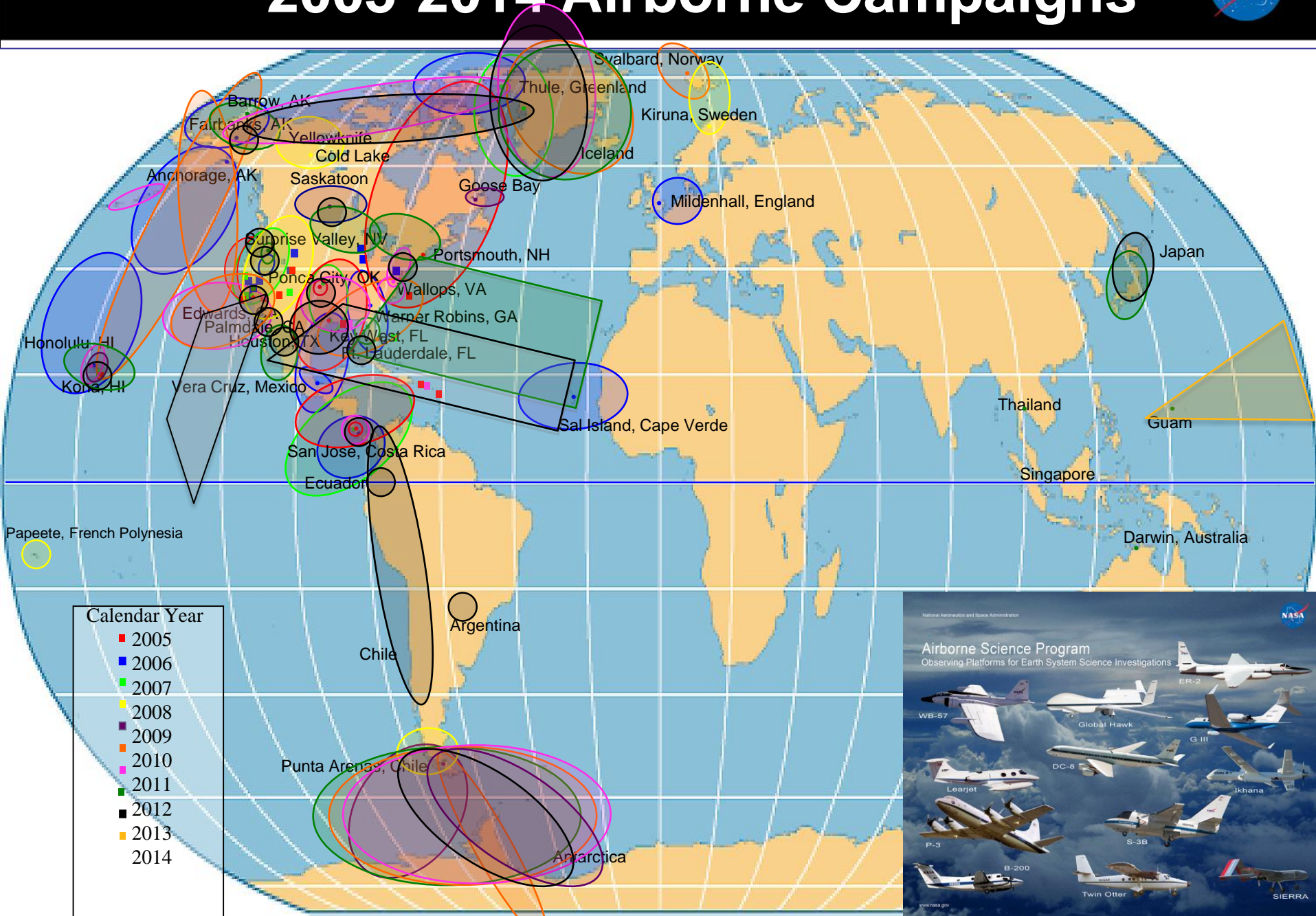
- The temporal and spatial location of clouds have a large impact on the projected air quality given a set of emissions. This tool is designed to provide accurate cloud information.
- Texas Commission for Environmental Quality (TCEQ) used this tool in their latest State Implementation Plans (SIPs)
- The State of Texas joined NASA Applied Sciences in funding 30% of the Project (~$310K)

2005-2014 Airborne Campaigns

Svalbard, Norway
Thule, Greenland
Kiruna, Sweden
Barrow, AK
Fairbanks, AK
Yellowknife
Cold Lake
Iceland
Anchorage, AK
Saskatoon
Goose Bay
Mildenhall, England
Surprise Valley, NV
Portsmouth, NH
Japan
Ponca City, OK
Wallops, VA
Edwards, CA
Warner Robins, GA
Palmdale, CA
Houston, TX
Key West, FL
Ft. Lauderdale, FL
Honolulu, HI
Thailand
Kona, HI
Vera Cruz, Mexico
Guam
Sal Island, Cape Verde
San Jose, Costa Rica
Singapore
Ecuador
Papeete, French Polynesia
Darwin, Australia
Argentina
Chile
Punta Arenas, Chile
Antarctica

Calendar Year
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011
- 2012
- 2013
- 2014

Airborne Science Program
Observing Platforms for Earth System Science Investigations

ER-2
WB-57
Global Hawk
G III
Learjet
DC-8
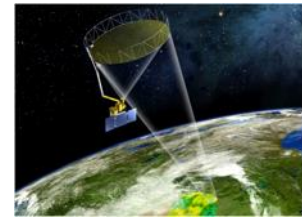Ikhana
P-3
S-3B
B-200
Twin Otter
SIERRA

Your Planet is Changing
Earth Right Now
We're on it!

GPM

OCO-2

RapidScat

CATS

SMAP